Direct Modeling of Pixel Grid Distortions for WL Systematics

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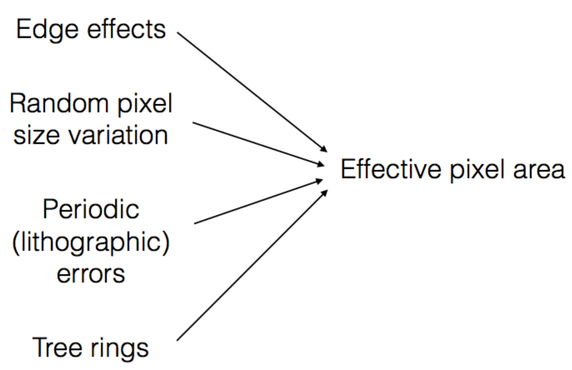
Introduction

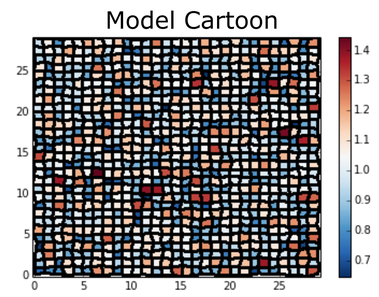
Understanding the impact of sensor effects on galaxy shape measurements and the PSF will be **critical to the success of LSST weak lensing science**.

While it is useful to characterize the impact of individual sensor effects in isolation, we take a different approach, recognizing systematic errors will come from net variations in **effective pixel area**.

This picture is a natural consequence of the attribution of pixel area variations to transverse electric fields in the silicon bulk (see, e.g. Stubbs 2013)



Step 1: Fitting a grid model

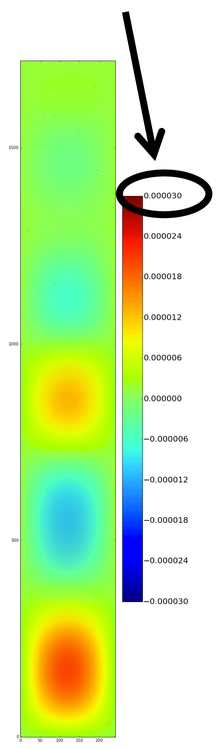


We use a maximum-likelihood method to fit an underlying pixel grid to co-added flat field data.

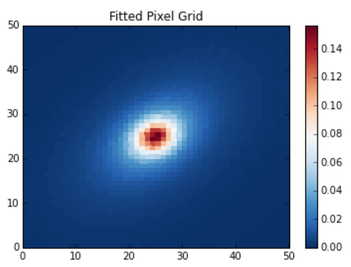
$$\ln \mathcal{L} = \sum_{\text{pixels i,j}} (A_{ij}(\text{vertices}) - \phi_{ij})^2 + \lambda ||\Delta \text{vertices}||^2$$

Formally, the model is underconstrained (NxM data points; 2*(N+1)(M+1) DOF), but **rectilinear initial state and small step size** constitute a strong prior that empirically regularizes the problem.

Model captures 99.99% of flux variations!

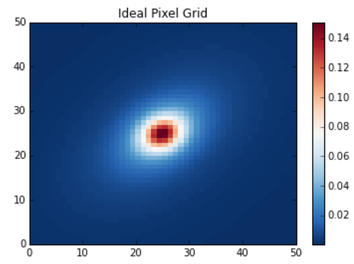


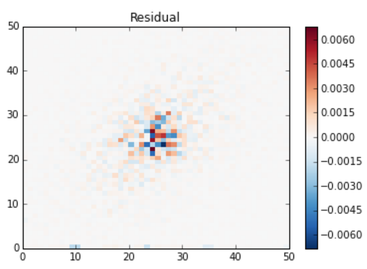
Step 2: Depositing sources



Having fitted a model of the underlying pixel grid, we can deposit a galaxy- or PSF-like source onto our fitted focal plane (variations exaggerated)

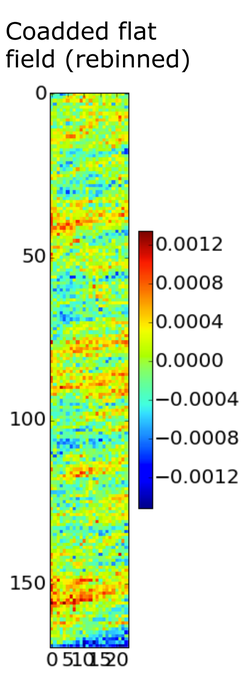
We then compare to what an ideal, rectilinear pixel grid would have observed.





These pixel-level residuals will lead to systematic errors on our catalog measurements.

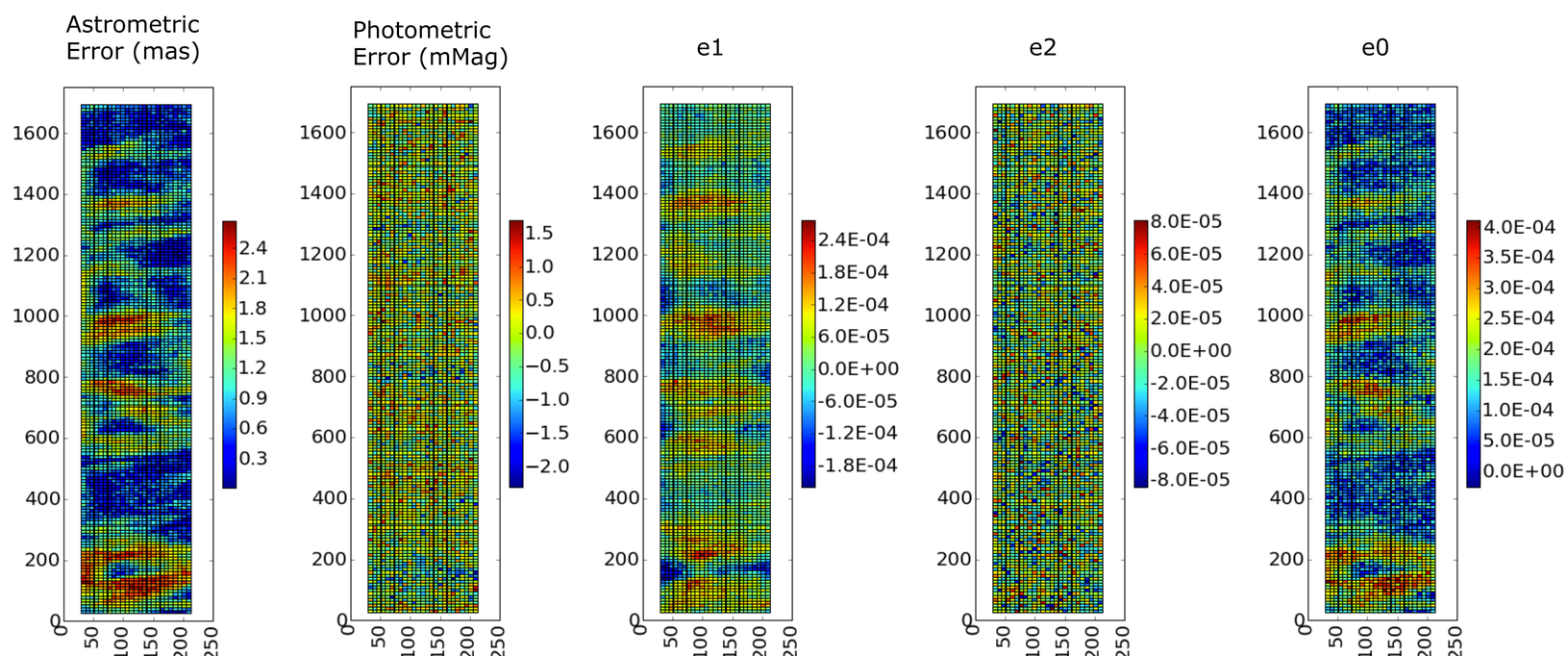
Step 3: Assessing Impact on Photometry, Astrometry, and Shape



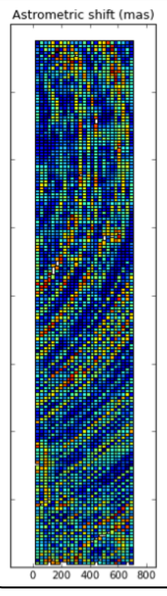
Here we map the observed differences in catalog parameters of PSF-like sources measured using adaptive moments.

Compare the spatial structure of a coadded flat field on the left with the maps of systematic deviations on the right.

All of the pixel-grid-induced errors are below LSST WL requirements

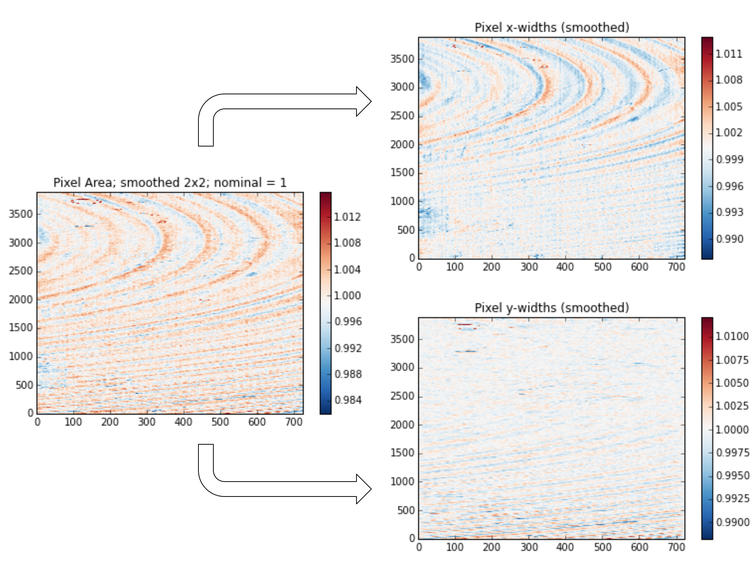


Model Validation



The CCDs used in the Dark Energy Camera have known tree rings (Plazas et al 2014), which are picked up by our model in measurements of both shape and astrometry (see left). Comparisons to star flat data from DECam are ongoing. Similar comparisons could be made to pinhole data from LSST CCDs.

The DECam fits give us confidence the fitting algorithm is working as desired. We expect pixel area distortions to occur in a direction perpendicular to tree rings, and this is observed in our fits at right.



Conclusions

We conclude from this analysis of net variations in effective pixel area that the science impact of static sensor effects in the central region of a prototype LSST CCD is below the level required for LSST weak lensing science.

We hope to test this conclusion on other LSST prototypes using data recently provided by Andrei Nomerotski. Thanks to Peter Doherty (Harvard) for providing the flat field data used in this study.

References
C. Stubbs. arXiv:1312.2313
A. Plazas et al. arXiv:1403.6127